Ⓨ Ontario

An Overview of
Senior Driver Collision Risk

Ministry of Transportation

Safety Policy Branch

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Senior Driver Collision Risk

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EXECUTIVE SUMMARY

Ontario has seen a dramatic increase in life expectancy and a declining birth rate. This has resulted in an aging driving population. The most dramatic changes have occurred in the oldest age groups. Drivers aged 70-79 and 80 and over accounted for 5.73 per cent and 1.14 per cent of the driving population in 1995 compared to 4.68 and 0.67 per cent in 1986, respectively. The over 80 age group has been the fastest growing age group in the Ontario driving population during the past decade.

If the amount of driving is taken into account, drivers in the oldest age group (80 and over) have collision rates which are much higher than those observed for middle-aged drivers. The relationship between driver age and crash involvement is best described as U-shaped. This means that the number of collisions per million kilometres driven per year is highest for young and old drivers with the lowest rates being observed for middle-aged drivers.

Collisions involving senior drivers have a number of unique characteristics. Crash-involved senior drivers are more likely to be cited for: failure to yield the right of way and illegal turns. They are less likely to be cited for: speeding, careless driving and impaired driving. There is also a substantial age-related increase in the proportion of collisions occurring in intersections. In fact, the proportion of drivers crashing in intersections increases substantially in the three oldest age groups. The trend is similar for both males and females. This helps explain why female and male drivers aged 80 and over are almost twice as likely to have collided at an angle (i.e. T-impact collisions) than their counterparts in the 16-19 age group. Angle collisions are more likely to occur in intersections or while entering or exiting from a private driveway. Older drivers are also far more likely to be involved in a collision during daytime hours under conditions of clear visibility. This may be due, in part, to their avoidance of bad-weather and nighttime driving.

Research confirms that older senior drivers are more likely to experience losses in the functional abilities needed to drive safely than drivers in other age categories. This is evident when we review the results of studies on their sensory, cognitive and psychomotor abilities. Researchers have reported on the link between visual attention and cognitive problems and collision involvement in older drivers. Moreover, attentional and cognitive impairments appear to be the most important component of the age-related decline in reaction time. The age-related decline in cognitive ability may combine with other performance deficits to further compromise driving performance. This is especially true of vision deficits. Age-related vision deficits are especially severe when the luminance level approximates nighttime conditions.

Senior drivers tend to compensate for losses in ability by reducing their annual distance driven, trip speed and freeway use. Senior drivers are also less likely to drive at night and during peak hours. The majority of senior drivers adapt quite well to any age-related impairments which may affect their driving performance.

The available research does not show a clear safety benefit associated with mandatory age-based road-testing policies. As a result of these findings, Ontario introduced a new licensing program for drivers aged 80 and over on October 28, 1996. The program incorporates four key elements: a vision assessment, knowledge test, driver record review and classroom instruction. In addition, all drivers aged 70 and over involved in an at-fault collision are road-tested. The program runs on a two-year cycle beginning at age 80. This new approach provides a reasonable, research-based alternative and remains one of the most stringent older driver programs in North America.

RÉSUMÉ

La population de l'Ontario a connu une augmentation remarquable de l'espérance de vie ainsi qu'une baisse de la natalité. Il en est résulté une augmentation de l'âge moyen des conducteurs sur nos routes. Les changements les plus notables se sont produits dans les groupes d'âges supérieurs. Les conducteurs et conductrices âgés de 70 à 79 ans et de 80 ans et plus représentaient 5,73 % et 1,14 % du nombre total de conducteurs en 1995, par rapport à des pourcentages respectifs de 4,68 % et de 0,67 % en 1986. Le groupe des conducteurs de 80 ans et plus est celui qui a affiché la plus forte croissance depuis les dix dernières années en Ontario.

Compte tenu du nombre de kilomètres parcourus au volant, les conducteurs appartenant à la catégorie la plus âgée, celle des personnes de 80 ans et plus, ont des taux de collisions beaucoup plus élevés que les conducteurs d'âge moyen. Pour bien saisir le rapport entre l'âge et le taux de collisions, on peut se représenter une courbe en U, ce qui signifie que le nombre de collisions par millions de kilomètres parcourus chaque année est plus élevé pour les jeunes conducteurs et les conducteurs âgés, et que les taux les plus faibles sont observés chez les conducteurs d'âge moyen.

Les collisions mettant en cause les conducteurs âgés présentent un certain nombre de traits particuliers. Les conducteurs âgés ayant causé une collision sont plus susceptibles de se voir imputer la responsabilité de l'accident au fait qu'ils ont omis de céder le passage ou qu'ils ont effectué un virage illégal. Ils ont moins tendance à se voir inculper d'excès de vitesse, de conduite imprudente et de conduite avec des facultés affaiblies. On note aussi une augmentation importante du taux d'accidents survenus aux intersections pour lesquels l'âge des conducteurs constitue un facteur. En fait, la proportion de collisions survenues à des intersections qui mettent en cause des conducteurs des trois groupes d'âge supérieurs augmente de façon substantielle. Cette tendance est la même pour les automobilistes de sexe masculin et féminin. Ce fait aide à expliquer la raison pour laquelle les conducteurs et les conductrices de 80 ans et plus risquent presque deux fois plus de provoquer des collisions à angle (c'est-à-dire des collisions à impact en té) que les conducteurs de 16 à 19 ans. Les collisions à angle risquent davantage de se produire à des intersections ou lors des manoeuvres pour sortir d'une entrée privée ou s'y engager. Les conducteurs plus âgés sont également beaucoup plus susceptibles d'être impliqués dans des collisions pendant les heures de jour, lorsque la visibilité est bonne. Cela pourrait en partie s'expliquer par le fait que les conducteurs de cette catégorie évitent la conduite par mauvais temps et le soir.

La recherche confirme que les conducteurs plus âgés sont davantage exposés à des diminutions des capacités fonctionnelles requises pour conduire de façon sécuritaire que les conducteurs des autres groupes d'âge. Il suffit pour s'en convaincre d'examiner les résultats d'études menées sur leurs capacités sensorielles, cognitives et psychomotrices. Des chercheurs ont fait état d'un lien entre, d'une part, l'attention visuelle et les difficultés cognitives et, d'autre part, le taux de collisions des conducteurs âgés. De plus, les déficiences attentionnelles et cognitives semblent constituer les facteurs les plus importants expliquant la détérioration du temps de réaction attribuable

à l'âge. La diminution de la capacité cognitive due au vieillissement pourrait s'ajouter à d'autres déficiences de fonctionnement pour compromettre davantage le rendement au volant. Ce constat est particulièrement vrai dans le cas des déficiences visuelles. Les déficiences visuelles liées à l'âge sont particulièrement prononcées lorsque le taux de luminance s'apparente à celui de la conduite de nuit.

Les conducteurs âgés ont tendance à compenser la diminution de leurs capacités en réduisant le nombre de kilomètres qu'ils parcourent chaque année au volant, en conduisant moins vite et en évitant les autoroutes. Les conducteurs du troisième âge sont également moins enclins à conduire la nuit et aux heures de pointe. La majorité d'entre eux s'adaptent assez bien aux déficiences attribuables à leur âge qui peuvent influer sur leur rendement au volant.

Les études dont nous disposons ne démontrent pas qu'il y aurait un avantage net du point de vue de la sécurité à instaurer des épreuves de conduite sur la route obligatoires en fonction de l'âge. En se fondant sur ces résultats, l'Ontario a mis en place, le 28 octobre 1996, un nouveau programme de renouvellement des permis de conduire pour les conducteurs de 80 ans et plus. Ce programme intègre quatre éléments : un examen de la vue, un test de connaissances, un examen du dossier de conduite et des cours en classe. En outre, tous les conducteurs de 70 ans et plus qui ont un accident avec responsabilité doivent subir une épreuve sur route. Le programme fonctionne selon un cycle de deux ans à compter de l'âge de 80 ans. Cette nouvelle façon de procéder constitue une solution de remplacement raisonnable, étayée par des recherches, et le programme demeure l'un des plus rigoureux en Amérique du Nord en ce qui concerne les conducteurs âgés.
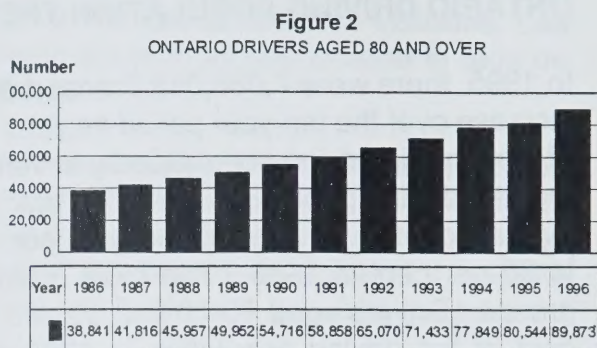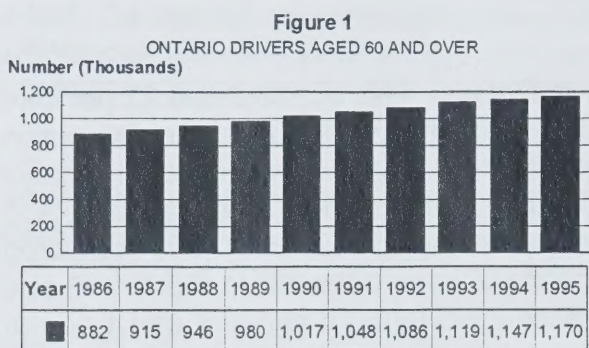
ONTARIO DRIVING POPULATION TRENDS

In 1995, there were 7,086,018 licensed drivers in Ontario. This constitutes a 22 per cent increase over the ten-year period beginning in 1986. Table 1 presents the age distribution of the Ontario driving population by seven age categories. A glance at the table indicates that the driving population has been aging during the past decade. Drivers aged 45 and over accounted for approximately 40 per cent of the driving population in 1995 compared to 36 per cent in 1986. The most dramatic changes have occurred in the oldest age groups. Drivers aged 70-79 and 80 and over accounted for 5.73 per cent and 1.14 per cent of the driving population in 1995 compared to 4.68 and 0.67 per cent in 1986, respectively. The upward trend is fairly uniform over the entire decade.

TABLE 1 - AGE DISTRIBUTION OF ONTARIO DRIVING POPULATION
(Percentage)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
16-19	5.07	5.12	5.08	5.14	5.00	4.86	4.70	4.78	5.14	5.09
20-24	11.62	11.08	10.52	10.04	9.76	9.55	9.32	9.11	8.92	8.67
25-44	47.31	47.70	48.09	48.38	48.60	48.30	47.75	47.21	46.65	46.31
45-59	20.82	20.79	20.85	20.86	20.87	21.34	21.98	22.49	22.88	23.42
60-69	9.82	9.91	9.96	9.97	9.93	9.88	9.90	9.83	9.70	9.65
70-79	4.68	4.71	4.74	4.82	4.99	5.17	5.36	5.52	5.60	5.73
80+	0.67	0.70	0.75	0.79	0.85	0.90	0.97	1.05	1.11	1.14
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The increases observed in the absolute number of older drivers are presented in Figures 1 and 2. Figure 1 shows a steady rise in the number of drivers aged 60 and over from 882,487 (15.2 per cent of the driving population) in 1986 to 1,169,800 (16.5 per cent of the driving population) in 1995. The increase in the absolute number of drivers aged 80 and over is even more substantial. Figure 2 shows that the number of drivers in this age group rose from 38,841 (0.67 per cent of the driving population) in 1986 to 80,544 (1.14 per cent of the driving population) in 1995. Moreover, the number of drivers aged 80 and over has been increasing at the rate of between eight and ten per cent per year over the entire decade.[1] The over 80 age group has been the fastest growing age group in the Ontario driving population during the past decade. If present trends continue, drivers aged 80 and over will make up about 2 per cent of the driving population by 2010 and peak at about 4.5 per cent of the driving population by the years 2030-2040.

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[1] The sole exception is the change observed between 1994 and 1995, when the population of drivers aged 80 and over increased only 3.5 per cent.

Figure 1
ONTARIO DRIVERS AGED 60 AND OVER
Number (Thousands)

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
■	882	915	946	980	1,017	1,048	1,086	1,119	1,147	1,170

Figure 2
ONTARIO DRIVERS AGED 80 AND OVER
Number

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
■	38,841	41,816	45,957	49,952	54,716	58,858	65,070	71,433	77,849	80,544	89,873

Nevertheless, it is important to emphasize that at the present time most people aged 80 and over do not have a valid driver's licence. In 1994, there were approximately 283,500 people aged 80 and over in Ontario (Statistics Canada, 1994). Thirty-four per cent (95,600) were males and 66 per cent (187,900) were females. In that same year, there were 77,849 licensed drivers aged 80 and over (49,862 males and 27,987 females). This indicates that about 27 per cent of the Ontario population aged 80 and over had a valid driver's licence in 1994. There were, however, dramatic gender differences. Fifty-two per cent of Ontario males aged 80 and over are licensed compared to only 15 per cent of the females.

The figures in the preceding paragraph contrast sharply with those observed for the Ontario population aged 45 to 59. In 1994, there were approximately 1,788,900 people aged 45-59 in Ontario (Statistics Canada, 1994). Approximately, 49.9 per cent (891,800) were males and 50.1 per cent (897,100) were females. In that same year, there were 1,597,906 licensed drivers aged 45 to 59 (866,014 males and 731,892 females). This indicates that about 90 per cent of the Ontario population aged 45 to 59 had a valid driver's licence in 1994. There was a smaller gender difference in the licensure rate. Ninety-seven per cent of Ontario males aged 45 to 59 were licensed compared to 82 per cent of the females.

The differences observed in the licensure rates for people aged 45 to 59 and those aged 80 and over reflect the increase in age-related medical conditions in the latter age group that make driving impossible and/or the inability to pay the expenses associated with automobile ownership. People aged 80 and over who continue to drive are in all likelihood those who are relatively healthy and/or wealthy.

Finally, if we compare the percentage of male and female drivers in the over 80 age group to the percentage of males and females in the overall population, we find males aged 80 and over are overrepresented among licensed drivers aged 80 and over. While males accounted for only about one-third of the over 80 population in 1994, they accounted for two-thirds of the licensed drivers. In fact, of the 77,849 licensed drivers, 49,862 (64 per cent) were males and 27,987 (36 per cent) were females. This compares to only a very

slight male overrepresentation in the 45 to 59 age group. Males accounted for 49.9 per cent of people aged 45 to 59 and 54.2 per cent of the licensed drivers. Females accounted for 50.1 per cent of people aged 45 to 59 and 45.9 per cent of the licensed drivers. The overrepresentation of males among drivers aged 80 and over must be borne in mind when assessing gender differences in age-related collision risk for drivers in that age group.

AGE-RELATED COLLISION RISK

The age-related collision risk for female and male drivers can be estimated using the induced exposure method. This approach provides a reasonably valid, inexpensive and unobtrusive way to measure driver exposure and assess collision risk. It is based on the analysis of aggregate motor vehicle collision statistics. The induced exposure method has been discussed extensively in the literature. It was developed several decades ago (Thorpe, 1967; Carr, 1970; Cerrelli, 1973). In recent years, considerable efforts have been made to develop the appropriate significance tests (Davis and Gao, 1992, 1993; Stamatiatidis and Deacon, 1995).

The statistic of interest in induced exposure analyses is the relative collision involvement ratio (RCIR) by driver gender and age group. Calculation of this ratio is relatively straightforward:

$$RCIR = \frac{\text{Probability (at-fault driver)}}{\text{Probability (not-at-fault driver)}}$$

If the RCIR equals one, then the drivers in an age category are as likely to be driving properly prior to a collision as they are to be driving improperly. Values greater than one indicate that drivers in a given age category are over-represented in collisions preceded by an improper driving action. Values less than one indicate that drivers in a given age category are under-represented in collisions preceded by an improper driving action.

The Ministry of Transportation of Ontario (MTO) accident database does not include fault codes. However, each collision record includes two fields for "apparent driver action" which correspond to fault codes. The apparent driver action fields contain codes for the pre-collision actions taken by the drivers of the first two collision-involved vehicles. Only one field is coded in the case of single vehicle collisions. There are thirteen driver action codes: one code for "driving properly" and twelve codes for improper driver actions. The twelve codes for improper driver actions can be combined into a single "driving improperly" code. This enables us to separate collision-involved drivers into those who drove properly (i.e. not-at-fault) before the collision and those who did not i.e. at-fault).

Aggregate collision data were obtained from the MTO accident database for the years 1992 to 1994 inclusive. A total of 1,048,867 (340,913 females and 663,204 males) Ontario drivers were involved in collisions during this three year period. The actions of 44,750 drivers (4.3 per cent) were excluded from the analysis for the following reasons:

- The apparent driver actions of drivers were coded as "unknown" or left blank.

- The ages of the drivers were unknown or left blank.
- Drivers were under the age of 16 and not legally licensed.

The excluded drivers included 7,702 female drivers and 37,048 male drivers (2.2 per cent and 5.6 per cent of the total female and male samples).

In general, most studies using the induced exposure method focus exclusively on two-vehicle collisions. The exclusion of single vehicle collisions is unfortunate because they are an important category of collision among young drivers. Most drivers involved in single vehicle collisions are coded as driving improperly. Single vehicle collisions were included in this analysis to ensure that the collision risk of younger drivers was not underestimated.

The RCIR values for female and male drivers are listed in Tables 2 and 3, respectively. The dependent variable is the propriety of the driver action (improper/proper). The independent variable is driver age (seven categories). Each table lists the RCIR values for seven age categories. The Chi-square value for each table indicates that the differences in the age distributions in each column of the dependent variable are statistically significant. The Chi-square test is sufficient to test for the significance of the cross-tabulated data presented in Tables 2 and 3. If a larger number of independent variables had been used, a logistic regression would have been the more appropriate technique (see Stamatiatidis and Deacon, 1995).

TABLE 2 - *RELATIVE COLLISION INVOLVEMENT RATIOS*
Collision-involved Female Drivers (1992-1994)

Age	A. Percentage Coded as Driving Improperly	B. Percentage Coded as Driving Properly	Relative Collision Involvement Ratio (A / B)
16 - 19	12.39	7.26	1.71
20 - 24	14.67	13.03	1.13
25 - 44	46.98	54.31	0.87
45 - 59	15.32	18.08	0.85
60 - 69	5.53	4.76	1.16
70 - 79	4.14	2.21	1.87
80 and over	0.96	0.35	2.74
Per Cent Total	100.00	100.00	

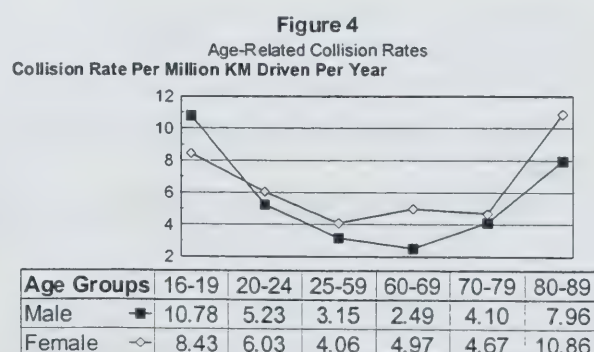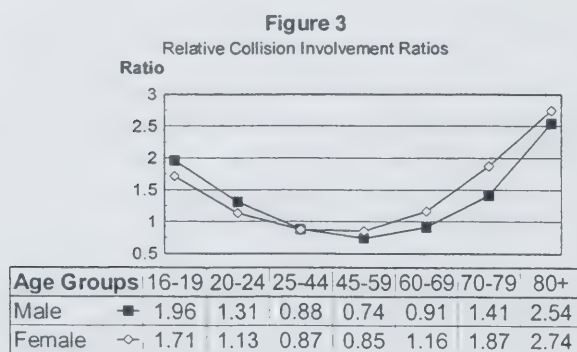Chi-square = 5308.244, 6 d.f., p < .001   N = 340,913

TABLE 3 - *RELATIVE COLLISION INVOLVEMENT RATIOS*
Collision-involved Male Drivers (1992-1994)

Age	A. Percentage Coded as Driving Improperly	B. Percentage Coded as Driving Properly	Relative Collision Involvement Ratio (A / B)
16 - 19	12.34	6.31	1.96
20 - 24	15.95	12.17	1.31
25 - 44	45.47	51.41	0.88
45 - 59	14.74	19.93	0.74
60 - 69	6.20	6.83	0.91
70 - 79	4.02	2.85	1.41
80 and over	1.27	0.50	2.54
Total	100.00	100.00	

Chi-square = 13713.108, 6 d.f., p < .001   N = 663,204

The RCIR values in Tables 2 and 3 are plotted in Figure 3. The resulting graphs for each gender are U-shaped and show a marked age-related increase in the RCIR after age 70 for both genders. Senior drivers aged 80 and over have RCIR values that exceed those of young drivers aged 16-19. Younger females (aged 16-44) have RCIR values which are lower than their male counterparts, while older female drivers have a substantially higher RCIR than older male drivers. Moreover, the gap widens considerably with age. Figure 3 underscores the substantial collision risk at both ends of the age spectrum.
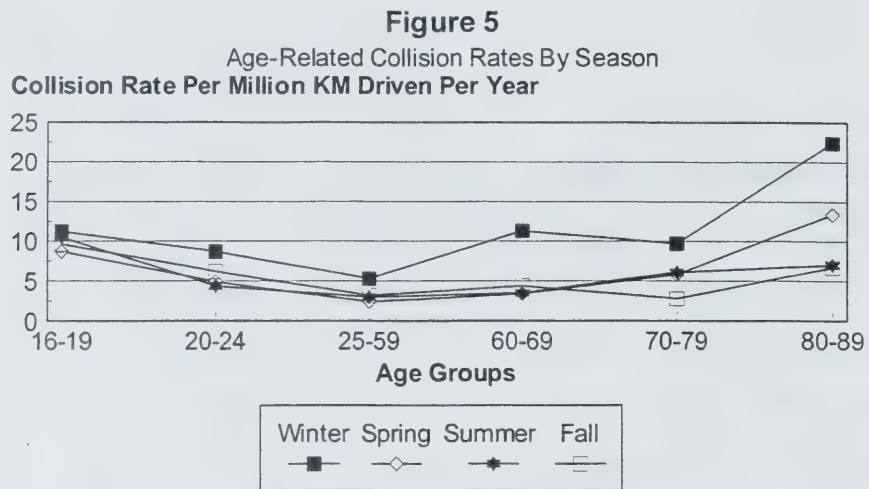
The induced exposure method for assessing crash risk yields a U-shaped curve which is similar to the one produced by the 1994 Ontario Exposure Survey (see Figure 4). The 1994 exposure survey obtained information on the amount and type of driving done by a large sample of Ontario drivers. The sample was stratified by age, sex and region of the province (Smiley et al., 1997). The daily distance driven for drivers in six age groups and both genders was calculated. Collision rates per million kilometres driven by gender and age were calculated using 1994 collision data and the distance driven data gathered during the exposure survey.

Figure 3
Relative Collision Involvement Ratios

Age Groups	16-19	20-24	25-44	45-59	60-69	70-79	80+
Male	1.96	1.31	0.88	0.74	0.91	1.41	2.54
Female	1.71	1.13	0.87	0.85	1.16	1.87	2.74

Figure 4
Age-Related Collision Rates
Collision Rate Per Million KM Driven Per Year

Age Groups	16-19	20-24	25-59	60-69	70-79	80-89
Male	10.78	5.23	3.15	2.49	4.10	7.96
Female	8.43	6.03	4.06	4.97	4.67	10.86

The similarity between the graphs in Figure 3 and Figure 4 seems to suggest that the induced exposure method does account for exposure to risk to some degree. It may be that the age distribution of collision-involved drivers who were driving properly provides an estimate of the proportion of driving done by drivers in a given age group. Theoretically, the proportion of collision-involved drivers aged 80 and over who were driving properly. should correspond to the proportion of drivers aged 80 and over who were likely to be on the road any given time during the year. The assumption we are making here is that collision-involved drivers who were driving properly are innocent victims who were randomly involved in a collision event. In other words, when someone is driving improperly prior to a collision they do not choose the gender and age of the other driver(s) involved in the collision. These other driver(s) just happen to be on the road and as such provide a snapshot of the age and gender distribution of drivers on the road.

It is important to emphasize that most senior drivers with valid licences choose not to drive or to drive very little. For this reason, the proportion of drivers aged 80 and over who are actually involved in a crash in any given year remains relatively small (approximately 4 per cent). By contrast, approximately 10 per cent of drivers aged 16-19 have been involved in a collision in any given year. This does not change the fact that drivers aged 80 and over have a relatively high collision involvement rate when kilometres driven are taken into account. Nevertheless, these statistics underscore the need to keep senior driver collision involvement in perspective.

Keeping collision involvement in perspective means considering the collision risk for drivers aged 80 and over not as a constant, but as a variable. This is the conclusion from a recent exposure to risk study conducted by the Ministry of Transportation of Ontario (Smiley et al., 1998). The Ministry conducted an exposure survey which gathered data year-round to ensure that seasonal variations in collision risk could be measured and analyzed. The survey was conducted from December, 1993 to November,1994. Three-day trip logs were mailed to a stratified random sample of 11,250 Ontario drivers. The mean daily kilometrage for six age groups was estimated and seasonal collision rates per million kilometers driven were calculated. As Figure 5 indicates, drivers aged 80-89 show the most dramatic seasonal fluctuations in collision risk. The winter collision rate of 22.4 is over three times higher than the rate observed in the fall (6.7). The collision rate in spring (13.4) is twice that observed in the summer and fall. When the youngest and oldest age groups are compared, it is evident that the collision risk of 80-89 year-old drivers is two times higher in winter and about 1.5 times in spring. The youngest drivers, however, have a collision risk that is substantially higher than the oldest drivers in summer and fall.

Figure 5

Age-Related Collision Rates By Season

Collision Rate Per Million KM Driven Per Year

The dramatic increase in the winter collision risk of the oldest driver age group should not be a surprising. The reduced hours of daylight, poorer visibility and poorer road conditions (especially reduced traction) would greatly increase the concentration and vigilance required on the road. As we shall see, the collision patterns typical of older drivers already suggest that one of their key performance deficits are precisely a reduction in their ability to concentrate and remain vigilant.

COLLISION INVOLVEMENT PATTERNS

Knowing that older drivers have a collision risk comparable to that of teenage drivers does not necessarily help us to develop the appropriate safety policies. It is essential that we understand the characteristics of collisions involving older drivers. This will enable us to identify some of the key causative factors behind collisions involving older drivers and help us focus our policy development efforts on specific driver behaviours and/or driving situations. In this section we will look a little more closely at how collisions involving older drivers in the 1992 to 1994 period differ from those involving young and middle-aged drivers.

All collision-involved drivers for the years 1992 to 1994 inclusive will be subdivided by gender and age (seven age categories). The following variables will be considered:

- Apparent Driver Action

- Initial Impact Type

- Collision Location

- Lighting Level

- Visibility

- Vehicle Damage Level

These variables are among those listed on the Accident Report Form. The form is completed by the police officer(s) investigating a motor vehicle collision. Each variable has a corresponding field on the form. The investigating officers fill in each variable field by entering the appropriate numerical or letter code for the most appropriate variable category. Completed reports are entered into the Ministry of Transportation of Ontario's Accident Data System. The variables listed above will help to identify some of the key difficulties encountered by senior drivers and, more specifically, the maneuvers that place them at greater risk of a collision.

Apparent Driver Action

The apparent driver action means the action each driver was taking immediately prior to the collision. This does not include any evasive action taken by the driver to avoid the collision. There are thirteen codes for apparent driver action, one code for "driving properly" and twelve codes for improper driver actions. Collision-involved drivers are said to be driving properly if they are proceeding with due regard for other drivers and cannot be faulted for involvement in the collision. All other driver action codes correspond to
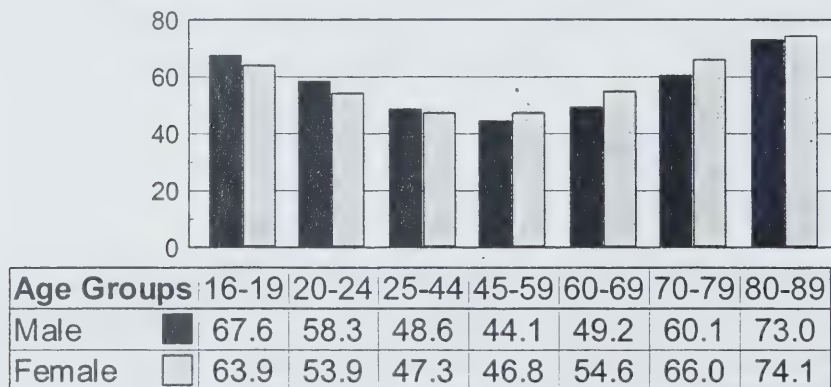
actions for which drivers can be faulted.

The assignment of an improper driving code does not necessarily correspond to the laying of charges under the Highway Traffic Act. It must also be emphasized that the assignment of these codes may reflect biases related to age and gender or outright coding errors (see Lyles et al., 1991). In a small percentage of crash reports the apparent driver action field is left blank or coded as "unknown" (eg. single vehicle crash with no witnesses).

Figure 6 shows the distribution of improper and proper driver actions for each of the seven age categories. The observed differences are statistically significant. The percentage of collision-involved drivers who drove improperly is dramatically higher at both ends of the age spectrum. Males are more likely to have been driving improperly than females in the two youngest age groups. There is a negligible gender difference for the over 80 age group. Three out of every four crash-involved females and males in the oldest age group are cited for an improper driver action. This compares to one out of every two middle-aged drivers.

Figure 6

Improper Actions By Collision-involved Drivers

Age Groups		16-19	20-24	25-44	45-59	60-69	70-79	80-89
Male	■	67.6	58.3	48.6	44.1	49.2	60.1	73.0
Female	□	63.9	53.9	47.3	46.8	54.6	66.0	74.1

The distribution of improper driver actions for both genders are presented in Tables 4 and 5. Each table lists the distribution of improper driver actions for each of the seven driver age categories. Only eight of the twelve potential improper actions are included in the tables. Two improper actions, speed exceeds posted limit and speed too fast for conditions were combined into one "excess speed" category. Two other improper actions, "speed too slow" and "wrong way on one way road" are relatively rare and were included in the "other" category. The observed differences in cell frequencies are statistically signficant.

TABLE 4 - *DISTRIBUTION OF IMPROPER DRIVER ACTIONS*
Collision-involved Female Drivers Cited for Driving Improperly
(1992-1994)
                    Cell Values = Row Percentages
                       (Row Totals = 100%)

Age	Following To Close	Lost Control	Disobey Traffic Control	Improper Lane Change	Excess Speed*	Improper Turn	Failure To Yield	Other**
16-19	13.76	18.38	5.50	3.99	17.10	8.72	21.32	11.23
20-24	16.48	16.86	6.34	4.44	16.75	7.90	20.09	11.14
25-44	14.92	16.84	6.42	4.45	14.58	8.42	22.87	11.50
45-59	11.19	15.16	7.96	5.00	11.85	10.20	26.84	11.81
60-69	8.91	12.01	9.31	5.17	7.30	12.14	33.22	11.94
70-79	7.50	9.80	9.45	5.51	4.40	13.53	38.23	11.59
80+	6.52	7.53	8.43	4.66	2.57	14.88	42.14	13.27

* Includes excessive speed and speed too fast for conditions.
** Combined total of less frequently cited improper actions such as speed too slow, improper passing and wrong way way on one way road.

Chi-square = 4898.970, 42 d.f., p < .001   N = 173,486

Key trends pertaining to older drivers in both tables are presented in bar chart format in Figures 7 and 8. It is evident that there is a marked age-related increase in collision-involved drivers who failed to yield the right of way or made an improper turn prior to the collision.

Failure to yield the right of way includes any failure to yield the road to vehicle(s) or person(s) with the right of way under provisions of the Highway Traffic Act. Overall, males are slightly less likely to be cited for failure to yield the right of way than females across all age groups. Nevertheless, the age-related trend is very similar for both genders: there is a steady and very substantial increase as drivers age. The highest incidence of this improper driver action for both males and females occurs in the 80 and over age group. Forty-two per cent of all collision-involved female drivers aged 80 and over who were cited for driving improperly, failed to yield the right way. Similarly, 39 per cent of their male counterparts were cited for this particular improper action. The incidence of failure to yield in the oldest age group is approximately twice that observed for drivers aged 16-19 (see Figure 7).

TABLE 5 - *DISTRIBUTION OF IMPROPER DRIVER ACTIONS*
Collision-involved Male Drivers Cited for Driving Improperly
(1992-1994)

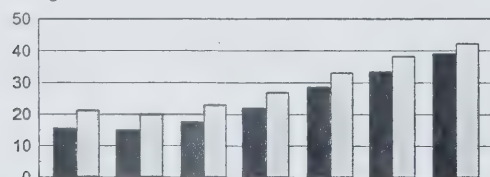## Cell Values = Row Percentages
(Row Totals = 100%)

Age	Following To Close	Lost Control	Disobey Traffic Control	Improper Lane Change	Excess Speed*	Improper Turn	Failure To Yield	Other**
16-19	13.56	18.45	6.19	3.90	22.61	6.71	15.62	12.97
20-24	16.20	17.00	6.56	4.63	20.91	6.06	15.08	13.55
25-44	17.04	15.07	6.45	5.16	17.36	6.99	17.45	14.47
45-59	15.42	13.02	6.98	5.87	13.55	8.59	22.12	14.43
60-69	12.74	10.56	8.53	5.95	9.40	11.08	28.52	13.23
70-79	10.00	8.78	9.10	5.99	6.61	13.44	33.43	12.65
80+	7.93	7.91	9.66	4.86	4.17	13.30	38.90	13.27

* Includes excessive speed and speed too fast for conditions.
** Combined total of less frequently cited improper actions such as speed too slow, improper passing and wrong way way on one way road.

Chi-square = 12656.574, 42 d.f., p < .001 N = 342,366

An "improper turn" is a turn made along a path or in a manner other than that prescribed by traffic laws. This would include turns made from or into lanes not prescribed by traffic laws, turns where the vehicle encroaches on lanes occupied by other vehicles and turns where the vehicle encroaches on crosswalks, sidewalks or strikes a fixed object on the roadside. Tables 4 and 5 indicate the incidence of this improper driver action also increases with age.

Figure 7
Improper Driver Action: Failure To Yield

Age Groups	16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males	15.6	15.1	17.5	22.1	28.5	33.4	38.9
Females	21.3	20.1	22.9	26.8	33.2	38.2	42.1

Figure 8
Improper Driver Action: Improper Turn

Age Groups	16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males	6.7	6.1	7.0	8.6	11.1	13.4	13.3
Females	8.7	7.9	8.4	10.2	12.1	13.5	14.9

In general, collision-involved females are more likely to have turned improperly than their

male counterparts, but this gender difference narrows with age. While the incidence of improper turns is not as substantial as failing to yield the right of way, collision-involved drivers in the oldest age group are about twice as likely to be cited for this improper action as are drivers in the youngest age group. This difference has been observed for both genders. Figure 8 provides a better illustration of these trends.

The incidence of collision-involved drivers cited for disobeying a traffic control (i.e. traffic signals and regulatory signs) also increases with age for both genders (Tables 4 and 5). The observed difference between the youngest and oldest age groups in each table is substantially smaller than the difference observed for failure to yield and an improper turn. Collision-involved older drivers who drove improperly are about one and one-half times more likely to be cited for this improper action than their younger counterparts. The patterns observed for each gender differ slightly. In Table 4, the age-related increase observed for females actually reverses for the oldest age group dropping from 9.45 per cent for 70-79 year olds to 8.43 per cent for female drivers aged 80 and over. Conversely, Table 5 shows a steady increase for the oldest male age groups, with the highest percentage observed for male drivers aged 80 and over (9.66 per cent).

Tables 4 and 5 also show a marked age-related decline in the incidence of three improper actions: following too closely, losing control of the vehicle and excessive vehicle speed. If we compare collision-involved female and male drivers in the youngest age group to those in the oldest age group, we find the youngest drivers are twice as likely to be cited for following too closely, two and one-half times more likely to be cited losing control and about six times more likely to be cited for either excessive speed or driving too fast for conditions. The similar age-related declines observed for both genders are not surprising when we consider that both following too closely and losing control of a vehicle are likely related to a vehicle's speed.

Initial Impact Type

The initial impact code describes the general path of the vehicle(s) immediately before the first impact. The distribution of these initial impact codes by the age category of collision-involved drivers are presented in Table 6 (females) and Table 7 (males). Each table shows the distribution of initial impact types for each of seven age categories. Two of the initial impact codes (angle collisions and turning movements) show a marked age-related increase and are presented in bar chart format in Figures 9 and 10. The differences observed in Tables 6 and 7 are statistically significant.

Initial impacts coded as "angle" correspond to collisions which occur at intersections and/or private drives where the initial directions of travel for both vehicles are about 90 degrees to one another and neither vehicle is in the act of turning. These collisions are also referred to as T-impact collisions. Figure 9 shows a marked age-related increase in proportion of angle collisions. An increase is discernable in the 45 to 59 age group and it

becomes larger for each successive age category. The largest percentage of angle collisions is observed for females (22.91 per cent) and males (21.50 per cent) aged 80 and over. Female and male drivers aged 80 and over are almost twice as likely to have crashed at an angle than their counterparts in the 16-19 age group. The proportion of females involved in angle collisions exceeds that of their male counterparts for each age category.

TABLE 6 - *DISTRIBUTION OF INITIAL IMPACT TYPES*
Collision-involved Female Drivers (1992-1994)

Cell Values = Row Percentages
(Row Totals = 100%)

Age	Angle	Approach	Rear	Single Motor Vehicle Other	Single Motor Vehicle - Not Attended	Side Swipe	Turning Move-ment	Other
16-19	12.88	2.14	25.24	20.35	3.39	8.57	26.67	0.75
20-24	12.72	2.14	28.99	17.40	2.03	9.89	25.93	0.90
25-44	13.85	2.32	30.25	14.85	1.95	9.86	25.78	1.14
45-59	15.94	2.35	27.69	13.65	1.88	10.14	27.01	1.33
60-69	19.62	2.12	21.83	11.66	3.17	10.00	30.30	1.30
70-79	21.32	1.61	17.90	9.80	4.28	10.21	33.74	1.15
80+	22.91	1.26	14.90	7.10	4.42	9.53	39.11	0.78

Chi-square = 4956.228, 42 d.f., $p < .001$ N = 348,291

An initial impact coded as a "turning movement" corresponds to collisions in which vehicles are in the act of turning and the impact location on one of the vehicles is on the side.   These collisions typically occur at intersections. Figure 10 indicates that the percentage of collisions preceded by turning movements varies little for drivers in the 16 to 59 age range (i.e. the first four age categories), but shows a clear upward trend in the three oldest age categories.   The largest percentages are observed for females (39.11 per cent) and males (35.36 per cent) aged 80 and over. The proportion of females involved in turning movement collisions exceeds that of their male counterparts in every age category.

TABLE 7 - *DISTRIBUTION OF INITIAL IMPACT TYPES*
Collision-involved Male Drivers (1992-1994)

Cell Values = Row Percentages
(Row Totals = 100%)

Age	Angle	Approach	Rear	Single Motor Vehicle Other	Single Motor Vehicle - Not Attended	Side Swipe	Turning Move-ment	Other
16-19	11.59	2.41	24.04	24.47	3.43	8.72	24.55	0.79
20-24	11.41	2.37	27.79	20.65	2.41	10.42	24.09	0.86
25-44	12.05	2.45	31.09	16.38	1.96	11.20	23.83	1.04
45-59	13.54	2.62	30.96	14.17	1.85	11.27	24.37	1.22
60-69	16.39	2.36	27.05	12.08	2.13	10.77	27.82	1.40
70-79	19.09	1.95	21.49	11.18	3.12	10.40	31.57	1.19
80+	21.50	1.65	16.94	9.74	4.68	9.20	35.36	0.93

Chi-square = 11253.870, 42 d.f., p < .001 N = 679,218

Tables 6 and 7 also show a marked age-related decline in the proportion of collisions coded as "single motor vehicle other." In this category of collision, a single vehicle is involved in a collision with a fixed object, pedestrian or animal. The overall trend across the seven age categories for both genders shows an inverse relationship between driver age and this impact type. This is not surprising given that many single vehicle collisions are often attributed to excessive speed and loss of control, two pre-collision driver actions which decline markedly with age. Crash-involved males are more likely to have had this type of impact. Males in all age categories are more likely to be involved in collisions of this type than their female counterparts.
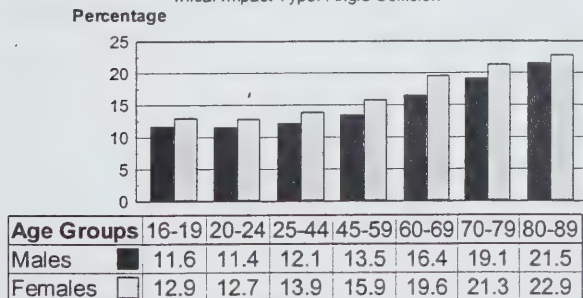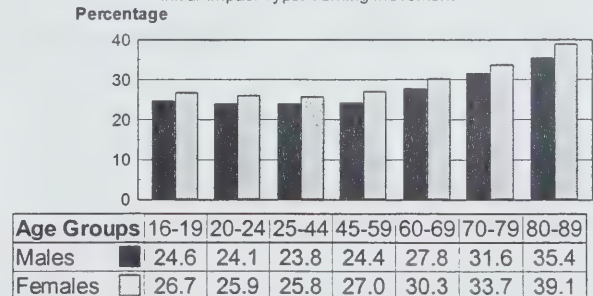
Figure 9
Initial Impact Type: Angle Collision
Percentage

Age Groups	16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males ■	11.6	11.4	12.1	13.5	16.4	19.1	21.5
Females ☐	12.9	12.7	13.9	15.9	19.6	21.3	22.9

Figure 10
Initial Impact Type: Turning Movement
Percentage

Age Groups	16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males ■	24.6	24.1	23.8	24.4	27.8	31.6	35.4
Females ☐	26.7	25.9	25.8	27.0	30.3	33.7	39.1

Drivers aged 80 and over are least likely to be involved in rear end collisions. These are collisions where vehicles are travelling in the same direction and the lead vehicle is struck in the rear. Tables 6 and 7 indicate that 15.4 per cent of females and 17 per cent of males in this age group are involved in rear end collisions. The highest incidence of this collision type for both genders is observed in the 25 to 44 age groups.

Other initial impact codes showing an age-related effect in Tables 6 and 7 are collisions where both vehicles approached each other. These are collisions where the initial direction of travel of each vehicle is opposite the other and at least one vehicle was impacted on the front (i.e. head-on). Females and males aged 80 and over showed the lowest incidence of this collision type, 1.26 and 1.65 per cent, respectively, compared to 2 per cent or higher for drivers aged 16 to 69.

Finally, Tables 6 and 7 indicate that drivers aged 80 and over are more likely to strike a vehicle that is stopped or parked. Males in this age group were slightly more likely to be involved in this type of collision than their female counterparts, 4.68 as opposed to 4.42 per cent. The lowest incidence of this collision type occurs among middle-aged drivers of both genders.

Collision Location

Four of eight location codes show substantial age-related differences. Three categories: "at railway crossing", "underpass or tunnel" and "overpass or bridge" were subsumed into the "other" category because the number of collisions occurring at these locations are negligible. The most dramatic age-related increase is observed for collisions occurring in the intersection. This collision category includes collisions occurring within the outermost lines of the crosswalks (or, in the absence of a crosswalk, the imaginary lines extending from the curb or highway boundary lines). Tables 10 and 11 show the distribution of collision locations for each of the seven age categories. The tables indicate that the proportion of drivers crashing in intersections increases substantially in the three oldest age groups. The trend is similar for males and females. Collision-involved female drivers are more likely to have crashed in an intersection than their male counterparts in every age category. The highest incidence is observed for females (40.93 per cent) and males (37.89 per cent) aged 80 and over. The differences observed in Tables 8 and 9 are statistically significant. Figure 11 presents these data in bar chart format.

TABLE 8 - *DISTRIBUTION OF COLLISION LOCATIONS*
Collision-involved Female Drivers (1992-1994)
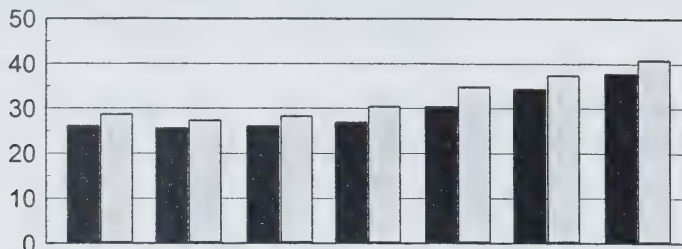
Cell Values = Row Percentages
(Row Totals = 100%)

Age	At or Near Private Drive	In Intersection	Intersection Related	Non-Intersection	Other
16-19	16.05	28.40	22.63	31.90	1.02
20-24	14.65	27.46	23.11	33.53	1.26
25-44	15.32	27.99	23.95	31.60	1.13
45-59	15.91	30.21	23.80	29.01	1.08
60-69	17.21	34.80	22.79	24.34	0.86
70-79	17.54	37.26	23.53	20.95	0.72
80+	18.10	40.93	24.21	16.15	0.61

Chi-square = 1892.882, 24 d.f., p < .001 N = 348,304

TABLE 9 - *DISTRIBUTION OF COLLISION LOCATIONS*
Collision-involved Male Drivers (1992-1994)

Cell Values = Row Percentages
(Row Totals = 100%)

Age	At or Near Private Drive	In Intersection	Intersection Related	Non-Intersection	Other
16-19	15.68	26.13	22.69	34.43	1.08
20-24	14.03	25.71	23.07	35.94	1.26
25-44	13.50	25.79	23.79	35.66	1.26
45-59	14.17	27.03	23.53	34.04	1.23
60-69	16.04	30.52	23.26	29.15	1.02
70-79	17.82	34.10	22.59	24.64	0.85
80+	18.80	37.89	21.00	21.41	0.91

Chi-square = 3433.435, 24 d.f., p < .001 N = 679,235

Figure 11

Collision Location: In Intersection

Percentage

Age Groups		16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males	■	26.1	25.7	25.8	27.0	30.5	34.1	37.9
Females	□	28.4	27.5	28.0	30.2	34.8	37.3	40.9

There is also an age-related increase in the percentage of collisions occurring at or near a private drive. This collision category includes those occurring at entries/exits which are not public roadways such as malls, plazas, schools, homes, hospitals and workplaces. The increase, however, is not as substantial as that observed for the "in intersection" category. The highest incidence of collisions at/near private drives occurred in the 80 and over category. The gender differences were neglible.

Lighting Level

Lighting level refers to the light condition at the time of the collision. There are nine lighting level codes. For the purposes of this analysis, lighting codes were subdivided into "daylight" and "other." Daylight is defined as the light conditions which normally occur between one half-hour after sunrise and one half-hour before sunset. All other codes correspond to lighting levels associated with dawn, dusk and night-time. This categorization (daylight/other) is more appropriate than looking at the time of the collision because the amount of daylight varies over the course of the year and we are more interested in tracking any age-related differences that occur in daytime collision-involvement. We would expect to see an increase in daytime collision involvement given the propensity of older drivers to avoid nighttime driving.

Figure 12 shows the distribution of lighting level for the seven collision-involved driver age groups. The graph confirms that the likelihood of being involved in a collision during daytime increases substantially with age. The observed difference across the seven age categories are statistically significant for both genders with a marked age-related increase that levels off in the oldest age groups.[2] Approximately 90.69 per cent of females aged

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2 The Chi-square for females is 5583.484 with 6 degrees of freedom (p < .001, N = 348,253). The Chi-square for males is 13482.140 with 6 degrees of freedom (p < .001, N = 679,115).

80 and over and 87.45 per cent of their male counterparts are involved in collisions during daylight hours. The lowest incidence of daylight collisions occurs in the youngest age group. These findings correspond to the results obtained in exposure surveys which consistently show a dramatic decrease in the amount of nighttime driving as drivers age (Smiley et al., 1991).

Figure 12
Collision Involvement By Lighting Level

Percentage

Age Groups		16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males	■	59.3	60.8	67.1	72.9	80.7	85.3	87.5
Females	☐	65.0	69.0	75.7	78.8	84.5	88.8	90.7

Environmental Condition

This variable includes eight categories that correspond to environmental conditions that may have contributed to the collision. These categories can be subdivided into two major categories: "clear" and "other." The "other" category includes adverse environmental conditions such as rain, snow, freezing rain, drifting snow, wind and fog. The environmental condition is coded as "clear" if there is an absence of precipitation or airborne matter which obscures visibility.

Figure 13
Collision Involvement By Environmental Conditions
Percentage Colliding With Clear Visibility

Percentage

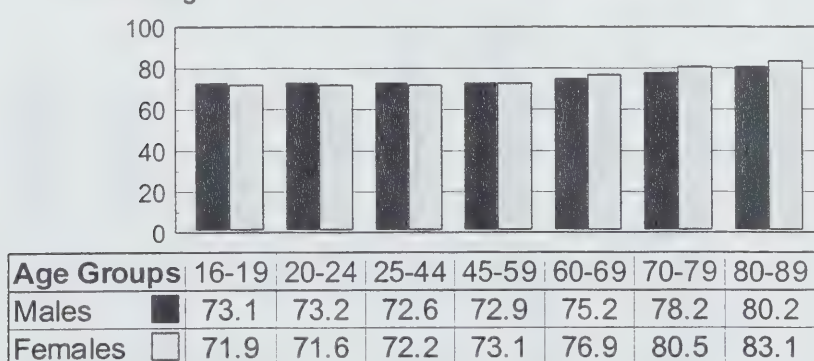| Age Groups		16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males	■	73.1	73.2	72.6	72.9	75.2	78.2	80.2
Females	☐	71.9	71.6	72.2	73.1	76.9	80.5	83.1

Figure 13 presents the distribution of environmental conditions for each of the seven age categories. It shows a slight age-related increase in the percentage of collisions occurring

under clear conditions for both genders. The observed differences for both genders are statistically significant.3 Any gender differences are neglible. These data indicate that older drivers are slightly less likely to be involved in a collision during adverse weather conditions. This reflects their tendancy to avoid driving under such conditions.
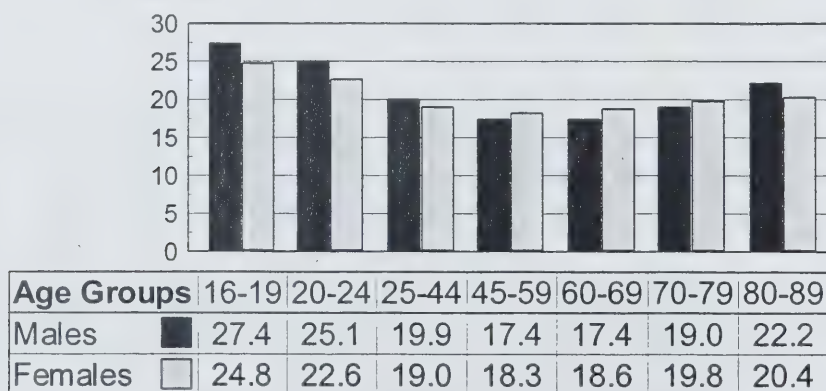
Vehicle Damage Level

This variable consists of the following five categories:

None   No visible damage
Light   Slight or superficial damage
Moderate   Vehicle must be repaired to meet legal requirements
Severe   Vehicle requires towing
Demolished   Vehicle cannot be repaired

Tables 10 and 11 present the distribution of four categories of vehicle damage by seven age groups. The "none" and "light" categories were combined.   Collision-involved drivers aged 16 to 19 are the most likely to sustain severe vehicle damage or a demolished vehicle. Middle-aged drivers are least likely to sustain such damage. There is a slight increase in severely damaged and demolished vehicles in the two oldest age categories. Figure 14 presents these data in a bar chart format. The bar graph shows a slight u-shaped trend. It also indicates there are substantial gender-related differences in the two youngest and the oldest age groups. The highest incidence of severe vehicle damage or a demolished vehicle still occurs in the youngest driver age groups.

Figure 14
Vehicle Damage in Collisions: Severe or Demolished
Percentage

Age Groups	16-19	20-24	25-44	45-59	60-69	70-79	80-89
Males ■	27.4	25.1	19.9	17.4	17.4	19.0	22.2
Females □	24.8	22.6	19.0	18.3	18.6	19.8	20.4

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3 The Chi-square for females is 689.004 with 6 degrees of freedom (p < .001, N = 348,304). The Chi-square for males is 611.091 with 6 degrees of freedom (p < .001, N = 679,235).

TABLE 10 - *DISTRIBUTION OF COLLISIONS BY VEHICLE DAMAGE LEVEL*
Collision-involved Female Drivers (1992-1994)

Cell Values = Row Percentages
(Row Totals = 100%)

Age	None or Light	Moderate	Severe	Demolished
16 - 19	37.82	37.42	18.23	6.53
20 - 24	40.25	37.15	17.06	5.54
25 - 44	44.38	36.67	14.78	4.17
45 - 59	45.35	36.33	14.32	3.99
60 - 69	45.14	36.29	14.53	4.04
70 - 79	44.09	36.09	15.31	4.51
80+	43.08	36.53	15.73	4.66

Chi-square = 1287.641, 18 d.f., p < .001 N = 335,399

TABLE 11 - *DISTRIBUTION OF COLLISIONS BY VEHICLE DAMAGE LEVEL*
Collision-involved Male Drivers (1992-1994)

Cell Values = Row Percentages
(Row Totals = 100%)

Age	None or Light	Moderate	Severe	Demolished
16 - 19	36.84	35.81	18.91	8.44
20 - 24	39.06	35.81	17.74	7.39
25 - 44	44.42	35.70	14.69	5.19
45 - 59	47.08	35.50	13.41	4.01
60 - 69	47.07	35.50	13.57	3.86
70 - 79	44.94	36.08	14.78	4.20
80+	41.68	36.12	16.83	5.37

Chi-square = 5259.801, 18 d.f., p < .001 N = 652,264

DISCUSSION

The trends identified in this report are similar to those reported in other jurisdictions and serve to reinforce some the observations made about collisions involving older drivers. First, it is evident that older drivers are more likely to have been driving improperly prior to a collision. The improper driver action is more likely to involve either a failure to yield or an improper turn. Collisions of this type are more likely to result in the initial impact frequencies we have observed for older drivers i.e. impacts while turning or angle impacts. These impact types tend to occur at intersections or while exiting/entering a private driveway. It is also evident that older drivers are far more likely to collide during daylight hours and slightly more likely to collide when there is clear visibility. Older drivers are also slightly more likely to be involved in collisions resulting in severe vehicle damage or a demolished vehicle than their middle-aged counterparts, but still less likely to be involved in such collisions than young drivers.

Nevertheless, collision-involved older drivers are at greater risk of injury than young or middle-aged drivers even in collisions where there is minimal vehicle damage. This increased risk of injury is due to the increased physical frailty that accompanies aging (Laux and Brelsford, 1990). For example, it is estimated that half the women and 20 per cent of the men aged 70 and over suffer from osteoporosis. A collision-involved driver with this condition will be at greater risk of a bone fracture. This helps to explain why older drivers are more likely to be involved in injury collisions in which they themselves are the injured party. Cerrelli (1989) reports that drivers aged 80 to 89 are twice as likely to be killed or injured in a collision where severe vehicle deformation occurred than drivers aged 16 to 24.

The collision patterns typical of older drivers suggest that one of the key performance deficits may be the decline in cognitive abilities. Driving situations which involve yielding the right of way, executing a turn and/or maneuvering a vehicle in an intersection correspond to some of the more demanding aspects of the driving tasks. Drivers are required to scan the road for oncoming vehicles, estimate vehicle velocities and execute a maneuver within an extremely short period of time - often several seconds.

Cognitive abilities include drivers' abilities to notice, recognize, interpret and understand cues about their immediate traffic environment. The research literature has consistently reported an age-related increase in cognitive impairment among older drivers.

Mourant and Mourant (1979) found older drivers performing freeway driving tasks required more time to look for particular cues and/or more time to extract the necessary information from these cues. Schiff and Oldak (1993) found drivers aged 65 and over responded more slowly to simulated traffic scenes involving driving hazards. Many persons aged 75 and over failed to see small objects associated with impending hazards. Hakamies-Blomqvist

(1993) reports 44% of the drivers aged 65 and over who were involved in fatal collisions were unaware of any impending danger prior to the collision compared to 26% of the drivers in a comparison group aged 26-40. This suggests a failure to perceive cues regarding impending hazards.

Researchers are also focussing on the relationship between driver age and the ability to divide attention while driving. Owsley et al. (1991) and Ball et al. (1993) have reported on the link between visual attention problems and collision involvement in older drivers. Ball and her associates have measured the useful field of view (UFOV) of a large sample of eye clinic out-patients. The UFOV is defined as the peripheral visual field available to a person focussing on a task in the central part of the visual field. UFOV is measured using a Visual Attention Analyzer. UFOV score tells us how well a person can identify a target silhouette in the periphery of a computer screen when the peripheral field is covered with silhouettes similar in size and shape and the person is also identifying a silhouette in the centre of the screen. Ball found that older drivers with more than a forty per cent reduction in UFOV as measured on the Visual Attention Analyzer are six times more likely to be involved in at-fault collisions.

Cognitive impairment appears to be the most important component of the age-related decline in reaction time. MacPherson et al. (1988) divide reaction time into pre-motor and motor time. Pre-motor time is the time required to recognize potentially dangerous situations, process the information and decide on a course of action. Motor time is the time needed to perform the necessary movements. MacPherson et al. found that observed differences in reaction time between young and old drivers were due prinicipally to slower pre-motor times. Mourant and Mourant (1979) report older drivers tend to have reaction times that are, on average, about 20 per cent slower than those observed for young drivers.

A considerable amount of the research on cognitive impairment (Friedland et al., 1988; Lucas-Blaustein et al., 1988; Donnelly et al., 1992; Tallman et al., 1993) has focussed on how the cognitive impairment associated with the early stages of dementia affects driving performance. The emphasis has been on the older driver, the segment of the driving population at greater risk for this disorder. Tallman et al. (1993) estimated that one-half of the older drivers diagnosed with mild dementia would be "getting by" in every day driving situations and could pass the current road test.

A recent Swedish study underscores the importance the dementia issue. Johansson (1997a; 1997b) reported one-third of the drivers aged 65 and over who died in motor vehicle collisions showed early signs of Alzheimer's disease. Alzheimer's disease is a progressive degenerative disorder that affects the brain causing memory problems, confusion, disorientation and behavioural changes. Presently, this disease is incurable and the long-term prognosis is poor.

Conservative statistical estimates indicate that the disease (along with other similar dementing illnesses) affects about eight per cent of people over age 65, 20 per cent of people over age 80 and 33 per cent of people over 85. Studies indicate that as the disease progesses beyond the early stages, a driver's collision risk can increase up to five times that of the normal driving population.

There is no simple medical test to diagnose Alzheimer's disease. Generally a tentative diagnosis can only be made after a patient has been followed-up and tested for many months. A definitive diagnosis is only possible with an autopsy to identify the characteristic pattern of nerve cell scarring and inflammation associated with this disease.

Johansson conducted neuropathological examinations of 98 drivers aged between 65 and 90 (average age 75) killed in collisions over a three-year period. Brain sections from the frontal and parietal areas of the associative cortex were examined and rated by two neuropathologists using an internationally accepted diagnostic protocol. These areas of the brain are involved in decision-making, judgement and visual-spatial ability.   The neuropathologists assessed the density of scarred and inflamed brain tissue and made a diagnosis using both a lower and higher (more conservative) density threshold.
Thirty-three per cent of the fatally-injured drivers had neuritic plaque (i.e. scarring) scores that made a diagnosis of Alzheimer's disease certain. In an additional 20 per cent, the plaque scores suggested Alzheimer's disease. It is, however, possible that some of the deceased drivers testing positive had been essentially asymptomatic when they were alive.

In short, Johansson considers the possibility that between 47 and 53 per cent of the fatally-injured drivers in his study may have had **incipient** Alzheimer's disease, that is to say, the early stages of the illness. It is likely that in a substantial proportion of these cases, the condition would not have been detected during a routine medical examination. Moreover, it should be recalled, that drivers with the early stages of the illness may still be able to pass a road test.

The results reported by Johansson indicate that the development of special road-testing protocols for drivers suspected of having this disease should be encouraged. Physicians should pay particular attention to older patient-drivers who present with the cognitive impairments associated with this condition. The Ontario Highway Traffic Act requires physicians to report to the Registrar of Motor Vehicles every patient who in the opinion of the physician is suffering from a condition that may make it dangerous for such a person to operate a motor vehicle.

Declines in cognitive ability may also combine with other performance deficits to further compromise driving performance. This is especially true of vision deficits. Hills and Burg (1978) found visual acuity alone is not a good predictor of future collision involvement. However, if poor visual acuity is combined with cognitive impairment then the ability to drive safely may be compromised.

There is certainly ample evidence that a substantial proportion of the older driver population has relatively poor visual acuity. Sivak et al. (1982) report that, on average, older drivers must be about 30 per cent closer to a highway sign than younger drivers to correctly identify the orientation of a target letter. Laux and Brelsford (1990) found 33% of drivers aged 80 and over and 14% of drivers aged 70-79 reported having trouble reading traffic signs at least "sometimes." They also found 22% of drivers aged 80 and over had trouble seeing traffic lights at least "sometimes" compared to none of the drivers aged 70-79.

These difficulties are compounded at night. Sivak et al. (1982) report that older drivers had mean nighttime sign legibility distances that were 65 to 77 per cent of those observed for younger drivers. All drivers in the study had approximately the same daytime acuity. Sturgis and Osgood (1982) report significant age-related losses in static acuity when the luminance level approximates nighttime conditions. Sturr et al. (1990) report that at a luminance level within the average nighttime driving range (0.78 cd/m^2) no one over age 65 was able to meet the 20/40 acuity criterion. Sturr et al. also report that at a luminance they claim exceeds average nighttime luminance levels on urban roads (2.45 cd/m^2) only 28% of drivers aged 65-74 and 4% of drivers aged 75 and over met the 20/40 acuity criterion.

In general, peripheral vision remains unaffected for the vast majority of older drivers. Johnson and Keltner (1983) report that only 13 per cent of their study subjects aged 65 and over experienced a loss in peripheral vision. Less than 5 per cent experienced severe peripheral vision loss.

Finally, it must be remembered that cognitive and vision impairments combine with the general slowing of body movement. Laux and Brelsford (1990) report an age-related decline in grip strength, neck flexibility and torso flexibility. MacPherson et al. (1988) also report older drivers have less flexible shoulder, torso and neck joint sites.

These performance declines may help us to better understand the collision involvement patterns we observe in the older driver population. It is important to emphasize, however, that collisions remain a relatively rare event for older drivers. In any given year, about 3.5 per cent of the drivers aged 80 and over are involved in a collision. This relatively low incidence can be attributed to the willingness of many older drivers to acknowledge their performance deficits and modify their driving habits accordingly. As a result, older drivers are:

- driving substantially lower annual distances than their younger counterparts

- less likely to drive during peak traffic periods, especially morning rush hour

- very unlikely to drive at night

- extremely unlikely to drink and drive

- generally drive at the posted speed limit or even slightly slower

- tend to avoid freeways

- reduce their driving during winter months

- more likely to plan their trips

These self-imposed limitations have been documented in travel behaviour surveys (Ministry of Transportation of Ontario, 1986; Huston and Janke, 1986; Lerner, 1990; Société de L'Assurance Automobile du Québec, 1991; Hu et al., 1993; Smiley et al., 1992; 1998).

AGE-BASED SAFETY PROGRAMS

The results reviewed so far indicate that drivers aged 80 and over would benefit from some form of program intervention. The debate, however, has centered on what type of program would be most effective. Until1996, Ontario required all drivers aged 80 and over to submit to annual vision, knowledge and road tests. The program had been in effect since 1936. Unfortunately, documents outlining the rationale for implementing the program at that time are not available. Over the years, the majority of older drivers have complained that the program is anxiety-inducing, disruptive and discriminatory. Moreover, as the discussion below will make clear, there is an absence of evidence showing compelling safety benefits accruing from mandatory age-based road test requirements.

Age-Based Testing

The safety benefits associated with mandatory age-based road testing are uncertain at best. Hull (1991) conducted an evaluation of age-based licensing policies in Australia with instructive results for those who view mandatory road testing as the answer. There is considerable variation in the road test policy across Australian states and territories. Five states and territories (including Victoria) do not require a road test for elderly drivers. The remaining three jurisdictions (New South Wales, South Australia and Tasmania) all require a road test. New South Wales requires an annual road test at age 80 for car drivers and at age 70 for tractor-trailer drivers. Tasmania requires an annual road test at age 85. South Australia requires a annual road test at age 70, but only for truck and motorcycle licences. Victoria and the Northern Territory are the only Australian jurisdictions that do not require **any** evaluation of older drivers; they are not required to test their vision, health or driving ability unless they are actually reported to the licensing authority by the police, health professionals or family and friends. The other jurisdictions all require periodic vision testing.

An analysis of the fatal crash rate for drivers over 60 across eight Australian jurisdictions (1985 to 1990) indicated that medical testing, vision testing and road testing of older drivers was not an effective means of reducing the fatal crash rate of older drivers. In fact, the fatal crash rate for elderly drivers in Victoria was exceeded by the jurisdictions with mandatory road testing over much of the period under observation. Hull's results confirmed findings from an earlier Victoria study; Torpey (1986) reported the Victorian injury collision rate for drivers aged 70 and over was substantially lower than other Australian states and territories. He concluded that states and territories with mandatory re-testing programs were not any more effective than Victoria at identifying unsafe older drivers. On the basis of these results, Torpey argued that the substantial costs associated with a re-testing program exceeded any potential safety benefits from reduced crash rates.

Recently, Lange and McKnight (1996) reached a similar conclusion when they evaluated two U.S. states with a mandatory age-based road testing policy. They report that Illinois

and Indiana (two states requiring periodic age-based testing of vision and driving skill) recorded a relative involvement ratio that was 7% lower than older drivers in Ohio and Michigan (two comparable states without such testing). The observed difference, however, did not appear in single-vehicle accidents where the older driver was at fault. In fact, just the opposite result was observed i.e. states with age-based road testing had a higher incidence of single-vehicle crashes. The authors speculate that age-based road testing may deter the safer, more conscientious drivers from seeking renewal. This may account for the observed increase in single-vehicle crashes.

The authors conclude it is unclear whether age-based road tests actually succeed in removing unsafe drivers from the road or merely inducing drivers to reduce their exposure. Their results suggest that age-based renewal testing may not significantly reduce the percentage of unsafe drivers among the elderly.

Levy et al. (1994) used multivariate regression equations to assess the safety benefits associated with different senior driver licensing requirements across all fifty states. Their data show considerable variation in older driver licence renewal requirements and the length of renewal terms across the U.S. Seven states lower their renewal terms for senior drivers at various ages. Four of these states require a two-year renewal cycle for seniors, two require a one-year renewal cycle and one state requires a three-year renewal cycle. Fourteen states tie a vision testing requirement directly to driver age. Two of these states (California and Louisiana) also add an age-based knowledge test requirement. Three of these states (Illinois, Indiana and New Hampshire) add a mandatory road test requirement, but not a knowledge test requirement. It should be noted, however, that 36 states have a vision test requirement at renewal for **all** drivers. Renewal terms for all drivers can range from every three years to every six years.

Levy et al. estimated older driver fatality rates per capita using a regression model which included demographic and licence renewal policy variables. They found states with mandatory vision testing every four years for senior drivers had a senior driver fatal collision involvement rate that was 7.9 per cent lower than states without any senior driver licence renewal policy. The incremental gain from adding either a knowledge test **or** road test every four years is a reduction of an additional four per cent.

This study suggests the safety benefits could be improved by lowering the renewal term to two years. An age-based vision test every two years would reduce the senior driver fatal collision involvement rate by 14.7 per cent. If either a knowledge **or** road test requirement were added to the vision test, the incremental gain would be an additional 11.1 per cent reduction.

In conclusion, the Torpey (1986), Hull (1991) and Lange and McKnight (1996) studies do not support a mandatory road test policy. Levy's findings suggest that the most empirically defensible age-based renewal policy would consist of a two-year renewal cycle along with

the combined use of both an age-based vision test and a knowledge test.

Driver Education

Senior driver education programs may assist older drivers in coming to terms with age-related performance deficits and their consequences. The classroom provides the most inexpensive and convenient setting for imparting knowledge about potential hazards and compensatory safe driving practices. McKnight (1988) notes that the dissemination of information to older drivers in the classroom requires only minimal changes to established adult learning principles. In fact, basic adult learning principles can be used providing the appropriate adjustments are made for visual and hearing impairments. McKnight stresses that these principles are very straightforward:

- Adults are uncomfortable with the lecture format and prefer interactive classroom instruction.

- Reading material reduces the burden on classroom instruction and enables program participants to learn at their own pace.

- Classroom instruction should use local, everyday examples familiar to participants to develop general safe driving principles.

- The classroom environment and learning aids must be designed with physical and other impairments in mind.

Fonseca (1994) contends classroom training programs should focus on the mental and physical problems that are attributable to aging or age-related medical conditions as well as the actual driving performance problems that stem from aging and age-related medical conditions. The course would then be more effective at improving older drivers ability to recognize the nature and possible consequences of mental and physical problems and teach them how to correct or compensate for them. These courses will only be successful if they help older drivers anticipate and avoid typical driving errors.

McCoy et al. (1993) suggest that driver education may improve the on-road driving performance of senior drivers. They compared the effectiveness of physical and perceptual therapy programs, a driver education course and traffic engineering interventions on senior driver performance. A sample of 105 volunteers were randomly assigned to six groups each featuring a different combination of treatments). Before and after measures on subjects' vision, visual perception, cognition, range of motion, brake reaction time, driving knowledge and on-road driving performance (as measured by a road test) were taken and compared.

All experimental groups recorded a positive percentage increase (seven per cent) in their

driving performance scores. The observed differences across countermeasures were not statistically significant. In other words, subjects who took the driver education course fared as well as those receiving other treatments or multiple treatments. It must be emphasized, however, that these findings are only suggestive due to the relatively small sample size.

The California DMV has recently evaluated the driver education component of an older driver insurance discount program (Janke, 1994). The Mature Driver Improvement (MDI) program was enacted in 1987. It entitles drivers aged 55 and over to 3 years of automobile insurance premium reductions if they choose to participate in a classroom driver improvement course.

The MDI course curriculum and accreditation procedures for schools wishing to teach the MDI course were developed by the California Department of Motor Vehicles. The MDI course offers information on how health and age-related physical changes affect driver performance, the driving performance effects of medications and alcohol, rules of the road and defensive driving techniques, trip planning and handling hazardous driving conditions.

Janke compared crash and citation rates of course graduates and comparison drivers. The MDI drivers were selected from the years 1988 to 1992 inclusive. The comparison drivers sampled randomly from the DMV's automated driver file. For the purposes of the tracking study, comparison group drivers were assigned the same reference dates as those in the MDI group.

Crash and citation rates were adjusted to correct for self-selection biases in age, gender, license class and prior driving history between subjects in the MDI and Comparison groups. The MDI group had significantly lower citation rates. However, the differences observed in the frequency of total and fatal/injury collisions did not yield a reliable and significant reduction in collision risk for course graduates.

A number of possible explanations for this result were considered. Completion of the MDI course may have increased graduates' knowledge of traffic laws and their confidence behind the wheel. This may have helped graduates to reduce the number of citations and prompted them to both increase the amount of driving and increase their exposure to challenging driving situations. It may, therefore, be possible that MDI graduates had a lower collision rate when miles driven are taken into account. This may provide a plausible explanation for the paradoxical finding: a reduction in citations without a corresponding reduction in overall crash rates. Usually, a reduction in citations is associated with a reduction in collision risk. The only way to confirm this hypothesis, however, is to collect data on the amount of driving done by both MDI graduates and controls.

The results of the MDI evaluation suggest more work needs to be done in the area of developing and evaluating education programs for older drivers. Older drivers remain excellent candidates for classroom instruction because, in general, they:

- are motivated to keep driving
- have time to attend class
- are amenable to acquiring information in an interactive classroom setting
- are law-abiding
- avoid risky driving situations

An evaluation of participants in a group education session program for Ontario drivers aged 80 and over indicates that older drivers are highly favorable to receiving information on age-related changes in driving performance and collision risk (Tasca, 1995). Courses, however, must be structured and delivered using sound adult learning principles. It is also important not to overestimate the role of classroom instruction. Classroom instruction can be a useful component in an older driver safety program when it is combined with diagnostic components that help identify older drivers who are potentially dangerous to themselves and others on the road. These are drivers who are unaware that their driving performance has deteriorated substantially.

The New Ontario Program

Until recently Ontario required all drivers aged 80 and over to take an annual vision, knowledge and road test. This program came into effect in 1936. While it is unclear what triggered the new program, it is doubtful that the program was developed in response to comprehensive research on aging and driving performance.

The introduction of the program was likely not controversial. Drivers aged 80 and over made up an infinitesimal percentage of the driving population - far less than the 1.14 per cent they account for today or even the 0.67 per cent they accounted for as recently as 1986. Moreover, in 1936, anyone driving at age 80 or older was already quite advanced in years when they had begun to drive. Older drivers were, therefore, also relatively inexperienced drivers. Automobiles had only became an affordable commodity for the middle classes during the 1920s. In Ontario, the increase in automobile ownership during that decade led to the introduction of driver licensing and road testing in 1927.

The aging issue probably arose when large numbers of older people began applying for licences. Given that automobiles were still relatively expensive in the 1930s, it does not seem unreasonable to suppose that many prospective licensees were well into middle age. If there was a lower age limit on licensure, administrators likely began to ponder whether an upper age limit was also warranted. The adoption of an annual mandatory re-testing program commencing at age 80 suggests that administrators opted for what at the time, was the least contentious solution.

Eventually, the program required drivers attaining the age of 80 to renew their licences annually by passing a vision test, knowledge test and road test. As the population of

drivers aged 80 and over grew, the Ministry received numerous complaints alleging that the program was discriminatory and burdensome. Many older drivers have complained that the road test was humiliating and the cause of considerable anxiety. Moreover, many driver examiners were reluctant to fail older drivers because 1) older drivers were singled out for road-testing on the basis of age alone and not tangible evidence of an inability to drive safely and 2) the mental anguish and hardship imposed on the older driver faced with licence revocation.

The lack of evidence demonstrating a clear safety benefit from the mandatory road test policy has led the Ministry to re-assess its older driver program. After reviewing the available evidence, it was decided that the mandatory annual road test policy could no longer be justified.

The result is a new age-based licence renewal program which includes the following mandatory components: vision screening, knowledge testing, driver record review and classroom instruction. The program came into effect on October 28, 1996. Under the new program, licence renewal occurs on a two-year cycle for drivers aged 80 and over. It is important to emphasize that classroom instruction is not being used as a stand-alone intervention, but rather as a complement to the diagnostic components of the program.

In the new program all drivers aged 80 and over, who meet the Ministry's vision standards and pass a knowledge test, must attend a group education session as a condition of re-licensure. Prior to beginning the group education session, the driving records of all participants are reviewed by group counsellors who have been trained to both deliver the course and review driving records. Group counsellors use the individual driving records to decide if any of the participating drivers should be road-tested prior to licence renewal.

The mandatory group education sessions are designed for approximately 10-15 people and last for approximately 90 minutes. The curriculum was developed specifically for older adults and offers information on age-related mental and physical impairments that may affect actual driving performance. The course reviews the possible consequences associated with these impairments and offers suggestions on how the older driver can compensate for them.

The new program is supplemented by other programs already in place to identify problem older drivers. First, any Ontario driver aged 70 and over who is involved in an at-fault collision will be required to take a road test. Under this provision, the older driver is road-tested as soon as possible and not at the time of licence renewal. Second, as previously discussed, Ontario requires physicians to report patients to the Registrar of Motor Vehicles once they have formed the opinion that a patient's medical condition may make the operation of a motor vehicle dangerous.

Senior drivers have been extremely supportive of the new program. It has been viewed

as reasonable and fair. A full-scale evaluation study is under way to assess its safety benefits. The evaluation study will track and compare the collision rates of a large sample of drivers in the previous program with those from a large sample of drivers in the new program.

CONCLUSIONS

The dramatic increase in life expectancy and a declining birth rate will result in a larger older driver population during the coming decades. If the amount of driving is taken into account, drivers in the oldest age group (80 and over) have collision rates which are much higher than those observed for middle-aged drivers.

Collisions involving senior drivers have a number of unique characteristics. Crash-involved senior drivers are more likely to be cited for: failure to yield the right of way, disregarding traffic signals and illegal turns. They are less likely to be cited for: speeding, careless driving and impaired driving. There is a substantial age-related increase in the proportion of collisions occurring while turning at intersections. Older drivers are also far more likely to be involved in a collision in daytime during conditions of clear visibility. This may be due, in part, to their avoidance of bad-weather and nighttime driving.

Human factors research confirms that older senior drivers are more likely to experience losses in the functional abilities needed to drive safely than drivers in other age categories. This is evident when we review the results of studies on their sensory, cognitive and psychomotor abilities. When these findings are added to those from statistical studies of older driver collision risk, it is clear that losses in these functional abilities are more evident among drivers aged 80 and over. The available evaluation research, however, does not show a clear safety benefit associated with mandatory road-testing policies. Ontario's new licensing program incorporates four key elements: a vision assessment, knowledge test, driver record review and classroom instruction. The program runs on a two-year cycle beginning at age 80. This new approach provides a reasonable, research-based alternative and remains one of the most stringent older driver programs in North America.

Finally, the reader should remember that many senior drivers compensate for losses in ability by reducing their annual distance driven, trip speed and freeway use. Senior drivers are also less likely to drive at night and during peak hours. The majority of senior drivers adapt quite well to any age-related impairments which may affect their driving performance.

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